

CHAPTER 40

OCCUPATIONAL RADIATION DOSE MANAGEMENT

Radiation Absorbed Dose

- It measures the radiation energy absorbed as a result of radiation exposure
- It is used to identify irradiation of patient
- *Units:* rad or Gy_t

- *Rationale:* higher levels of scatter & leakage radiation

It is best to position the x-ray tube under the patient during mobile & C-arm fluoroscopy!

Radiation Exposure

- Radiation intensity in air
- *Units:* roentgen or Gy_a

Effective Dose

- It identifies the biologic effectiveness of the radiation energy absorbed
- It is applied to occupationally exposed persons & to population exposure
- *Units:* rem or Sv

Rem

- The unit of effective dose
- It is used for radiation protection purposes

OCCUPATIONAL RADIATION EXPOSURE

Radiologic Personnel

- *Dose Limit:* 50 mSv/yr
- *Occupational Exposure in General X-ray Activity:* not exceed 1 mSv/yr

OCCUPATIONAL RADIATION EXPOSURE OF RADIOLOGIC PERSONNEL

Exposure Category	Value
Average whole-body dose	0.7 mSv/yr
Those receiving less than the minimum detectable dose	53%
Those receiving <1 mSv/yr	88%
Those receiving >50 mSv/yr	0.05%

Fluoroscopy

- It contributes to the highest occupational exposure of diagnostic x-ray personnel
- Personnel exposure is related directly to the x-ray beam-on time
- X-ray Tube Over The Table
 - *Advantage:* in terms of image quality
 - *Disadvantage:* higher personnel exposures

Remote Fluoroscopy

- It results in low personnel exposures
 - *Rationale:* personnel are not in the x-ray examination with the patient

Interventional Radiology

- Personnel receive higher exposures
 - *Rationale:* longer fluoroscopic x-ray beam-on time
- *Contribute to Higher Exposure:*
 - Absence of protective curtain
 - Use of cineradiography
- *Dose Limit:* 500 mSv/yr

Extremity monitoring must be provided for interventional radiologists!

Mammography

- Personnel exposures are low
 - *Rationale:* less scatter radiation due to low kVp operation
- Protection:
 - Long exposure cord
 - Conventional wall
 - Window wall
- It does not require protective shielding
 - *Rationale:* mammographic x-ray units have personnel protective barriers
 - *Composition:* lead glass, lead acrylic or plate glass

Computed Tomography

- Personnel exposures are low
 - *Rationale:*
 - CT x-ray beam is finely collimated
 - Only secondary radiation is present in the examination room

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Surgery

- Occupational exposure for nursing personnel & other working in the operating room & intensive care unit is near zero
- It is not necessary to provide occupational radiation monitors for such personnel

Mobile Radiology

- It contributes to the highest occupational exposure of diagnostic x-ray personnel
- Wear Occupational Radiation Monitor:*
 - Radiologic technologist
 - Anyone who is required to immobilize or hold patients
 - Personnel who regularly operate C-arm fluoroscope
 - Personnel who regularly in the immediate vicinity of C-arm fluoroscope
- Dose Limit:* 50 mSv/yr
- Average Exposure:* <1 mSv/yr

RADIATION DOSE LIMITS

Maximum Permissible Dose (MPD)

- The dose of radiation that would be expected to produce no significant radiation effects
- It has been replaced by dose limits

Dose Limit (DL)

- Maximum permissible occupational radiation dose
- It is specified only for occupational exposure
- Current DL:* 1 mSv/week

DLs imply that if received annually, the risk of death would be less than 1 in 10,000!

Whole-Body Dose Limits

- Annual Dose:* 50 mSv

A. Occupational Exposures

- Effective Dose
 - Annual:* 50 mSv
 - Cumulative:* 10 mSv x age

2. Equivalent Annual Dose For Tissues & Organs

- Lens of the Eye:* 150 mSv
- Thyroid, Skin, Hands & Feet:* 500 mSv

B. Public Exposures (Annual)

- Effective Dose, Frequent Exposure: 1 mSv
- Equivalent Dose For Tissues & Organs:
 - Lens of the Eye:* 15 mSv
 - Skin, Hands & Feet:* 50 mSv

C. Education & Training Exposures (Annual)

- Effective Dose: 1 mSv
- Equivalent Dose For Tissues & Organs
 - Lens of the Eye:* 15 mSv
 - Skin, Hands & Feet:* 50 mSv

D. Embryo-Fetus Exposure (Annual)

- Total Equivalent Dose:* 5 mSv
- Equivalent Dose in 1 Month:* 0.5 mSv

E. Negligible Individual Dose (Annual): 0.01 mSv

Current DLs are based on a linear, nonthreshold dose-response relationship; they are considered to represent an acceptable level of occupational radiation exposure!

Occupational Exposure

- It is described as dose equivalent in units of mSv or mrem

Dose Limit

- It is specified as effective dose (E)

WEIGHTING FACTORS FOR VARIOUS TYPES OF RADIATION

Types of Energy Range	Radiation Weighting Factor (Wr)
X-rays & gamma rays, electrons	1
Neutron, energy <10 keV	5
10 keV-100 keV	10
>100 keV-2 MeV	20
>2 MeV-20 MeV	10
>20 MeV	5
Protons	2
Alpha Particles	20

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Effective Dose (E)

- *Formula:* $E = \text{Radiation Weighting Factor } (W_r) \times \text{Tissue Weighting Factor } (W_t) \times \text{Absorbed Dose}$

Radiation Weighting Factor

- It depends on the LET of the radiation

Tissue Weighting Factor

- It accounts for the relative radiosensitivity of various tissues & organs
- *Higher Value of W_t :* more radiosensitive

Collar Monitor-Reported Value

- *Conversion factor:* 0.3
 - Apply to estimate the effective dose

Dose Limits For Tissue & Organs

- *Whole-Body:* 50 mSv/yr
- *Skin:* 500 mSv/yr
- *Extremities:* 500 mSv/yr
- *Lens of the Eye:* 150 mSv/yr

Public Exposure

- *General Population:* 1 mSv/yr
- *Hospital Workers:* 1 mSv/yr
 - Not radiology employees
- *1 mSv/yr:* the DL that medical physicists use when computing the thickness of protective barriers
- *Area Occupied By General Public:* <1 mSv/yr
- *Area Occupied By Radiation Workers:* <10 mSv/yr

Educational Considerations

- *Students <18:* <1 mSv/yr
- *Whole-Body:* 20 mSv/yr

REDUCTION OF OCCUPATIONAL RADIATION EXPOSURE

Fluoroscopy & Mobile Radiography

- They contribute to 95% of occupational radiation exposure

Guidelines for Reducing Occupational Exposure

- During Mobile Radiography
 - Wear an apron
 - Maintain maximum distance from the source
 - Never direct the primary beam toward oneself or others
- During Fluoroscopy
 - Minimize x-ray beam-on time
 - Step back from the table if not needed
 - Use shielding
 - Apron, curtain, Bucky slot cover & the radiologist
- During Radiography
 - Stand behind the control booth
 - Never direct the primary beam toward the control booth barrier

Each mobile x-ray unit should have a protective apron assigned to it!

The exposure cord on a portable x-ray unit must be at least 2 m long!

The useful beam should never be directed toward the operating console!

Occupational Radiation Monitoring

- It refers to procedures instituted to estimate the amount of radiation received by individuals who work in a radiation environment
- Three Types: film badges, thermoluminescence dosimeters (TLD) & optically-stimulated luminescence dosimeters (OSL)

Level of Occupational Exposure

- Depends on the type of activity
- Depends on the frequency of activity

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Occupation radiation monitoring is required when there is any likelihood that an individual will receive more than 1/10 of the recommended dose limit!

The occupational radiation monitor offers no protection against radiation exposure!

Film Badge

- Pack of photographic film used for approximate measurement of radiation exposure to radiation workers
- It is the most widely used & most economical type
- *Metal Filters:* aluminum or copper
- *Advantages:*
 - Inexpensive
 - Easy to handle
 - Easy to process
 - Reasonably accurate
 - They have been used for several decades
- *Disadvantages:*
 - Not reusable
 - Sensitive to temperature & humidity
 - Can't be worn for >1 month
 - *Rationale:* possible fogging due to temperature & humidity

TLD

- *Composition:* lithium fluoride (LiF)
- *Advantages Over Film Badge:*
 - More sensitive & accurate
 - As low as 5 mR
 - Not sensitive to temperature & humidity
 - Can be worn for 1 year
- *Principal Disadvantage:* cost

OSL

- *Advantage Over Film Badge & TLD:*
 - More sensitive
 - As low as 1 mR

Wearing of Occupational Radiation Monitor

- *General Use:* in front at waist or chest level

- *Fluoroscopy:* positioned on the collar above the protective apron
- *Pregnancy:* wear more than one radiation monitor

Control Monitor

- It measures background exposure during transportation, handling & storage

Protective Apparel

- It must be worn during fluoroscopy & mobile radiology
- *Thicknesses:*
 - 0.25 mm Pb – required
 - 0.5 mm Pb – normal
 - 1 mm Pb
- *Protective Aprons:* wrap-around type

It is known that 0.5 mm lead equivalent protective aprons represent a workable compromise between unnecessary weight & desired protection!

Position

- Remain as far from the patient as possible
- Keep the front of the apron facing the radiation source
- Take step or two backwards from the table when it is not required
- Use the dead man foot switch

Patient Holding

- Use mechanical immobilization device
- A relative or a friend should be asked to help
- *Last Resort:* hospital employees may used to hold patients

Radiology staff should never hold patients!

Pregnant Technologist/Radiologist

- Dose Limit: 0.5 mSv/month
- *DL for Fetus:* 5 mSv
- He/she should be provided with a second personnel monitoring device positioned under the protective apron

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- *Red*: collar badge
- *Yellow*: waist level

MANAGEMENT PRINCIPLES

Three Steps into the Radiation Protection Program

- New employee training
- Periodic in-service training
- Counseling during pregnancy

Under no circumstance should termination or an involuntary leave of absence occur as a consequence of pregnancy!

Emphasize

- Effective DL
 - 50 mSv/yr or 5000 mrem/yr
- Environmental Background Radiation
 - 1 mSv/yr
- Occupational Exposures
 - Closer to the latter than the former